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## (54) Tip clearance control apparatus.

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## Description

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates generally to gas turbine engines and, more specifically, to a clearance control apparatus and method capable of maintaining circumferentially uniform tip clearances for rotating blades.

### Description of the Related Art

In a typical aircraft gas turbine engine, a turbine section and a compressor section operate from a common rotor or "spool". The compressor section includes several rows of rotating blades mounted on the rotor, thus constituting the rotor assembly portion of the compressor section, and several rows of stator vanes mounted on a compressor casing, thus constituting a stator assembly portion of the compressor section. Each row of rotating blades and adjacent row of stator vanes is referred to as a "stage" of the compressor section.

The turbine section includes at least one row of rotating blades mounted on the rotor, thus constituting a rotor assembly portion of the turbine section, and at least one row of stator vanes mounted on a stator casing, thus constituting the stator portion of the turbine section.

In a dual rotor-type gas turbine engine such as is illustrated in Fig. 1, which is a schematic view of a General Electric Model CF6-50 aircraft gas turbine engine, a low pressure compressor section 10 and a low pressure turbine section 12 operate from a common rotor 14. A high pressure compressor section 16 and a high pressure turbine section 18 operate from a common rotor 20 which is coaxial with the rotor 14. The turbine sections 12 and 18 are driven by exhaust gases from a combustor 22 and thus drive the compressors 10 and 16, respectively.

The circumferential clearance between the tips of each row of rotating blades of the turbine section, and the corresponding annular surface of the stator portions, such as the stator shrouds, should be kept uniform to achieve optimum engine performance. However, typically for an engine in which the thrust is reacted away from the engine center line, high power conditions cause "backbone bending" of the engine's casings. Backbone bending thus causes the axes of the rotor and stator structures to be non-concentric. In the past, the stator shroud axis has been ground offset relative to the corresponding rotor axis to ensure uniform tip clearances around the circumference at take-off (high power) conditions. As schematically illustrated in Fig. 2(a), the offset results in a circular path 24 of the rotating blade tips of a row of turbine blades being eccentric with respect to the corresponding stator shroud surface 26. The amount of offset "o" is the vertical distance between the rotor axis 24c and the stator shroud axis 26c when the engine is in a cold operating condition (prior to engine start). It should be understood that the amount of offset and the size of the clearance have been exaggerated in Figs. 2(a)-2(c) for the sake of illustration.

As shown in Fig. 2(b), when the engine is operating under high power conditions, such as at full throttle (take-off), the diameter of the circular path 24 increases due to thermal expansion of the turbine blades, and backbone bending displaces the rotor axis 24c downwardly so that the rotor axis becomes substantially coincident with the stator axis 26c, thereby creating the desired uniform circumferential clearance $c_1$.

At low power conditions, such as at cruise power, the backbone bending effect is negligible and the offset "o'" reappears an shown in Fig. 2(c), thereby creating an undesirably large blade tip clearance $c_2$ on the lower portion of the engine, and a very close clearance $c_3$, (potentially a tip rub) at the top of the engine. The close clearance $c_3$ limits the effectiveness of existing active clearance control (ACC) systems such as those which duct cooling air to the stator shrouds symmetrically around the shroud circumference in order to cause uniform thermal contraction of the stator shroud. While uniform contraction may reduce the clearance of $C_2$, it may also eliminate gap $C_3$ and create an undesirable tip rub.

One proposal for solving this problem is shown in EP-A-0492865 which is a document according to Art 54(3) EPC. In this proposal the shroud of the turbine is unevenly heated or cooled to produce ovalization of the shroud.

## SUMMARY OF THE INVENTION

The present invention seeks to provide a tip clearance control apparatus and method for a gas turbine engine capable of producing a circumferentially uniform clearance between rotor and stator components under various operating conditions.

The present invention also seeks to counteract backbone bending of a rotor without having to grind the stator shroud so as to define a stator shroud axis which is offset from the rotor axis.

According to the invention, there is provided a tip clearance control apparatus in a gas turbine engine having a turbine section and a compressor section operating from a common rotor having a rotor axis, the compressor section including a compressor rotor assembly portion having plural rows

of rotary compressor blades mounted on the common rotor, a compressor stator assembly portion having plural rows of compressor stator vanes mounted on a compressor stator casing, each pair of adjacent rows of rotary compressor blades and compressor stator vanes comprising a compressor stage, the turbine section including a turbine rotor assembly portion having at least one row of rotary turbine blades mounted on the common rotor, each rotary turbine blade having a tip, and a turbine stator assembly portion having at least one row of stator vanes mounted on a turbine stator casing and a stator shroud mounted on the turbine stator casing circumferentially around each row of rotary turbine blades, each stator shroud having a stator shroud axis which is coincident with the rotor axis when the engine is in a cold, no power condition and when the engine is running at a low power condition, the tip clearance being defined as a circumferential space between the rotating turbine blade tips of a given row and an opposing surface of the corresponding turbine stator shroud and being circumferentially uniform during the no power and low power operating conditions, the rotor being positioned relative to the turbine stator assembly portion by bearing means supported by a plurality of struts mounted on a frame, the hollow struts being radially disposed at equidistant intervals around the rotor axis, each strut having a longitudinal axis substantially parallel to the rotor axis, the apparatus including a source of pressurized cooling air having a flow rate proportional to engine power and conduit means for delivering the pressurized cooling air to a selected group of the plurality of hollow struts at a temperature sufficient to induce thermal contraction of the group of hollow struts, thereby opposing a downward shift of the rotor axis during high power engine operation and maintaining the circumferentially uniform tip clearance.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

Fig. 1 is a schematic view of an aircraft gas turbine engine of known construction;

Figs. 2(a), 2(b) and 2(c) are schematic views illustrating tip clearances under cold, high power, and low power operating conditions, respectively, and illustrating a known clearance control technique for a gas turbine engine;

Fig. 3 is an partial longitudinal cross-sectional view of a portion of a gas turbine engine employing the tip clearance control apparatus and method of the present invention taken along line III-III of Fig. 7;

Fig. 4 is an enlarged longitudinal sectional view through one of the plurality of struts of the compressor rear frame of the gas turbine engine of Fig. 3 taken along line IV-IV of Fig. 7;

Fig. 5 is a transverse sectional view taken along line V-V of Fig. 4;

Fig. 6 is a perspective view of an air baffle used in the clearance control apparatus and method of the present invention; and

Fig. 7 is a transverse sectional view taken along line VII-VII of Fig. 3 and showing the arrangement of compressor rear frame struts.

## BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Fig. 3, a portion of a gas turbine engine 28 incorporating the apparatus and method of the present invention is illustrated in partial longitudinal cross section. The engine 28 is a General Electric Model CF6-80A/C2, modified to include the tip clearance control apparatus of the present invention, and is similar in construction to the model CF6-50 engine schematically illustrated in Fig. 1, details of construction being deleted in Fig. 3 for clarity. The engine 28 includes a two-stage high pressure turbine section 30 having two rows 32 and 34 of rotating blades 36 and 38, respectively. The rows of blades 32 and 34 are mounted on respective disks 40 and 42, the two disks 40 and 42 constituting part of a rotor 44 which includes a shaft portion 46.

A multi-stage high pressure compressor section 48 includes several rows, such as row 50 of rotating blades 52 mounted on the rotor 44 and several rows, such as row 54, of stator vanes 56 mounted on the stator casing 58.

The rotor 44 has a rotor axis 60r and the shaft portion 46 thereof is journalled for rotation by axially displaced rotor bearings 62 and 64 supported and positionally fixed by a frame 66 of the engine. Although the frame 66 is technically the rear frame of the high pressure compressor section 48, it is understood that other frame structures of an engine may support the bearings.

The compressor rear frame 66 includes an annular engine casing 68 and a plurality of hollow support struts 70, 71, 73, 75, 77, 79, 81, 83, 85, and 87 (Fig. 7), of which strut 70 is illustrated in Fig. 3. Each strut is integrally formed with the casing 68 and has a longitudinal axis oriented substantially parallel to the rotor axis 60r, the respective axes of the plural struts being disposed radially at equiangularly spaced intervals around the rotor axis 60r, as shown in Fig. 7. As illustrated in Figs. 3-5, strut 70 has an airfoil shape with two opposite side walls 70a and 70b which converge at their respective, opposite axial ends 70c and 70d

to provide leading and trailing edges, respectively. An interior chamber 72 is defined by the side walls 70a and 70b, a radially outer wall portion 68a of the engine casing 68 and a radially inner wall portion 74a of a rotor support structure 74.

The high pressure turbine section 30 includes a stator casing 76 to which is mounted a row 78 of stator vanes 80, and two stator shrouds 82 and 84 which are disposed annularly around the tips of the rotating blades 36 and 38, respectively. A first clearance 86 is defined as a space between the tips of the rotating blades 36 and an inner surface of the stator shroud 82, while a second clearance 88 is defined as a space between the tips of the rotating blades 38 and an inner surface of the stator shroud 84.

The stator shroud axes 60s for the shrouds 82 and 84 are coincident with the rotor axis 60r when the engine is cold and when operating at low power (low r.p.m.s), as shown in Fig. 3. Under high power conditions (high r.p.m.s), backbone bending, if not otherwise compensated for, will result in the rotor axis 60s shifting vertically downwardly relatively to the stator shroud axis 60s (in the orientation of Fig. 3), thus rendering the circumferential tip clearance non-uniform.

According to the present invention, thermal contraction of a selected group of the radially disposed struts 70, 71,... and 87 shifts the location of the rotor axis 60r upwardly to compensate for the downward shift attributable to operational conditions such as backbone bending. This is accomplished by introducing cooling air into the hollow interior 72 of the selected group of struts.

Cooling air is bled from one of the stages of the high pressure compressor section 48 and delivered to the selected group of struts through corresponding conduits 90 coupled to the respective inlet ports 92 provided for the struts of the selected group. Heat generated by operation of the engine 28 causes uniform thermal expansion of the plurality of struts. Cooling air introduced into selected ones of the hollow struts causes thermal contraction of the selected struts by heat transfer which results in radial upward shifting of the bearings 62 and 64 and thus of the rotor axis 60r. The cooling air exits the struts through exhaust openings 74b, 74c, and 74d provided in the rotor support structure 74.

In order to ensure uniform thermal contraction in the radial direction as well as efficient heat transfer, an air baffle 94 is placed inside each hollow strut of the selected group. Each air baffle is hollow and shaped substantially in the shape of the struts and thus has opposite side walls 94a and 94b (Fig. 5), which converge at their respective opposite axial ends to form fore and aft edges 94c and 94d, respectively. The side walls 94a and 94b oppose the inner surfaces of the strut side walls 70a and 70b, respectively, and are perforated with openings 94e so that cooling air entering a baffle inlet 94f is directed against the inner surfaces of the side walls 70a and 70b. The cooling air discharged from the hollow struts can be vented or reused for other purposes, such as for sump seal pressurization or turbine component cooling.

To determine which of the struts should be cooled, it should be realized that backbone bending results in a vertically downward shift in the rotor axis 60r relative to the stator axis 60s. In order to compensate for the shift, the cooled and thus thermally contracted struts should be a group located above a horizontal medial plane $P_1$ of the rotor 44, and preferably symmetrically disposed relative to the vertical medial plane $P_2$, as shown in Fig. 7, so that the direction of force vector $V_1$ (backbone bending) is equal but opposite to the restoring force vector $V_2$ (thermal contraction). It should be expected, however, in practical implementation of the present invention, that net displacement of the rotor axis 60s either upwardly or downwardly may occur when the forces are not exactly equal.

Struts 70, 71 and 87 are located above the horizontal medial plane $P_1$ and substantially centered on and/or symmetrical to the vertical medial plane $P_2$. Thermal contraction of struts 70, 71 and 87 produced by the cooling air from the compressor section will shift the rotor axis 60r upwardly to counteract a downward shift which occurs under full power conditions. Struts 73 and 85 could also be thermally contracted by use of cooling air, although their contribution to rotor axis shifting would be marginal due to their minimal angular displacement from plane $P_1$.

Other sources of cooling air may be employed, such as air bled from the low pressure compressor discharge (not shown). Thermal expansion of a selected group of struts below the horizontal medial plane $P_1$ achieved by using heated air bled from the combustor or exhaust nozzle (not shown) could be used, as an alternative to, or in combination with thermal contraction to achieve the same results. Moreover, other distortion vectors may be corrected, such as vector $V_3$, so long as the selected group of cooled struts produces a correction vector $V_4$ substantially equal but opposite vector $V_3$ (for example, by cooling at least struts 73 and 75 and possibly 71 and 77 as well). Of course, whichever struts are cooled (or heated) would be provided with appropriate air baffles, inlets, outlets, etc. to communicate cooling (or heating) air therethrough.

Since the flow rate of air from the compressor stages is dependent on engine running speed, the cooling rate is a function of the engine speed unless flow controllers are used. Thus, the present

invention can be "passive", simply by having flow rate and thus cooling capacity proportional to engine running speed, or "active" by using flow controllers to modulate flow as needed. Accordingly, flow rate controllers, such as throttle valves disposed in the conduit, with suitable actuators responsive to the engine operating conditions, can be used to adjust the flow rate to achieve the required correction factor. Modification of existing ACC system controllers can be used to position the flow control valves full open at idle and full throttle and to throttle back the cooling air at cruise conditions.

The number of struts (ten) illustrated in Fig. 7 is particular to the General Electric Model CF6-80A/C2 aircraft engine. This engine will have particularly satisfactory results using the present invention due to the bearing configuration in which the rotor bearings determine the position of the rotor axis, and are positionally supported by an arrangement of struts. Other engines having a different number of struts and/or other bearing support structures which are adaptable to thermal contraction or expansion likewise can be adapted to use the tip clearance control apparatus and method of the present invention.

## Claims

1. A tip clearance control apparatus in a gas turbine engine (28) having a turbine section (30) and a compressor section (48) operating from a common rotor (44) having a rotor axis (60r), the compressor section (48) including a compressor rotor assembly portion having plural rows of rotary compressor blades (52) mounted on the common rotor (44), a compressor stator assembly portion having plural rows of compressor stator vanes (56) mounted on a compressor stator casing (58), each pair of adjacent rows of rotary compressor blades (52) and compressor stator vanes (56) comprising a compressor stage, the turbine section (30) including a turbine rotor assembly portion having at least one row of rotary turbine blades (36,38) mounted on the common rotor (44), each rotary turbine blade (36,38) having a tip, and a turbine stator assembly portion having at least one row of stator vanes (80) mounted on a turbine stator casing (76) and a stator shroud (82,84) mounted on the turbine stator casing (76) circumferentially around each row of rotary turbine blades (36,38), each stator shroud (82,84) having a stator shroud axis (60s), the rotor axis (60r) being substantially coincident with the stator shroud axis (60s) when the engine is in a cold, no power condition and when the engine is running at low power, the tip clearance being defined as a circumferential space (86,88) between the rotating turbine blade tips of a given row and an opposing surface of the corresponding turbine stator shroud (82,84) and being circumferentially uniform during no power and low power conditions, the rotor axis (60r) bring positioned relative to the stator axis (60s) by bearing means (62,64) supported by a plurality of hollow struts (70-87) mounted on the compressor section rear frame, the hollow struts (70-87) being radially disposed at equiangular intervals around the rotor axis (60r), each strut (70-87) having a longitudinal axis substantially parallel to the rotor axis (60r), and a source of pressurized cooling air at a flow rate proportional to engine power, and a conduit (90) delivering the pressurized cooling air to a selected group of the hollow struts (70,71,87) at a temperature sufficient to induce thermal contraction of the selected group of the hollow struts (70,71,87), thereby opposing a downward shift in the rotor axis (60r) during high power engine operation, and maintaining the circumferentially uniform tip clearance.

2. A tip clearance control apparatus according to claim 1, characterized further in that the group of hollow struts (70,71,87) is above a horizontal medial plane ($P_1$) of the rotor (44) and centred on a vertical medial plane of the rotor.

3. A tip clearance control apparatus according to claim 2, characterized further in that each hollow strut (70,71,87) of the group includes an interior chamber (72) defining two opposite side walls (70a,70b) which converge at opposite axial ends to form a leading edge (70c) and a trailing edge (70d), a radially inner wall and a radially outer wall, an inlet port (92) formed in the radially outer wall and an exhaust port (74) formed in the radially inner wall.

4. A tip clearance control apparatus according to claim 3, characterized further in that an air baffle (94) is disposed in each hollow strut (70,71,87) of the group and has two perforated side walls (94a,94b) which oppose inner surfaces of the two side walls (70a,70b) of each corresponding hollow strut (70,71,87) and an inlet (94f) coupled to the inlet port (92) of each corresponding hollow strut (70,71,87).

5. A tip clearance control apparatus according to claim 1, characterized further in that the source of pressurized air is a selected one of the compressor stages, and wherein the conduit (90) is a pipe leading from the selected compressor stage to each of the hollow struts

(70,71,87) of the selected group of struts.

**Patentansprüche**

1. Spitzenspalt-Steuereinrichtung in einem Gasturbinentriebwerk (28) mit einem Turbinenabschnitt (30) und einem Verdichterabschnitt (48), die von einem gemeinsamen Rotor (44) mit einer Rotorachse (60r) arbeiten, wobei der Verdichterabschnitt (48) einen Verdichterrotorteil mit mehreren Reihen von Verdichterlaufschaufeln (52), die auf dem gemeinsamen Rotor (44) angebracht sind, einen Verdichterstatorteil mit mehreren Reihen von Verdichterleitschaufeln (56) aufweist, die auf einem Verdichterstatorgehäuse (58) angebracht sind, wobei jedes Paar benachbarter Reihen von Verdichterlaufschaufeln (52) und Verdichterleitschaufeln (56) eine Verdichterstufe bilden, wobei der Turbinenabschnitt (30) einen Turbinenrotorteil mit wenigstens einer Reihe von Turbinenlaufschaufeln (36, 38), die auf dem gemeinsamen Rotor (44) angebracht sind, wobei jede Turbinenlaufschaufel (36, 38) eine Spitze hat, und einen Turbinenstatorteil aufweist, der wenigstens eine Reihe von Leitschaufeln (80), die auf einem Turbinenstatorgehäuse (76) angebracht sind, und einen Statormantel (82, 84) enthält, der auf dem Turbinenstatorgehäuse (76) in Umfangsrichtung um jede Reihe von Turbinenlaufschaufeln (36, 38) herum angebracht sind, wobei jeder Statormantel (82, 84) eine Statormantelachse (60s) hat, wobei die Rotorachse (60r) mit der Statormantelachse (60s) im wesentlichen zusammenfällt, wenn das Triebwerk in einem kalten Zustand ohne Last ist und wenn das Triebwerk bei kleiner Leistung umläuft, wobei der Spitzenspalt als ein Umfangsraum (86, 88) zwischen den umlaufenden Turbinenschaufelspitzen einer gegebenen Reihe und einer gegenüberliegenden Oberfläche des entsprechenden Turbinenstatormantels (82, 84) gebildet ist und in Umfangsrichtung gleichförmig ist während der Zustände ohne Leistung und mit kleiner Leistung, wobei die Rotorachse (60r) relativ zu der Statorachse (60s) durch eine Lagereinrichtung (62, 64) positioniert ist, die durch mehrere hohle Streben (70-87) gehaltert sind, die auf dem hinteren Rahmen des Verdichterabschnitts angebracht sind, wobei die hohlen Streben (70-87) an gleichwinkligen Intervallen um die Rortorachse (60r) herum radial angeordnet sind, wobei jede Strebe (70- 87) eine Längsachse hat, die im wesentlichen parallel zu der Rotorachse (60r) ist, und eine Quelle von unter Druck stehender Kühlluft bei einer Strömungsrate, die proportional zu der Triebwerksleistung ist, und eine Leitung (90) aufweist, die die Kühldruckluft an eine gewählte Gruppe von hohlen Streben (70, 71, 87) bei einer ausreichenden Temperatur liefert, um eine thermische Kontraktion der gewählten Gruppe von hohlen Streben (70, 71, 87) hervorzurufen, wodurch einer Abwärtsverschiebung in der Rotorachse (60r) während eines Hochleistungs-Triebwerksbetriebs entgegengewirkt wird und der in Umfangsrichtung gleichförmige Spitzenspalt beibehalten wird.

2. Spitzenspalt-Steuereinrichtung nach Anspruch 1, weiterhin dadurch gekennzeichnet, daß die Gruppe hohler Streben (70, 71, 87) oberhalb einer horizontalen Mittelebene ($P_1$) des Rotors (44) und auf einer vertikalen Mittelebene des Rotors zentriert ist.

3. Spitzenspalt-Steuereinrichtung nach Anspruch 2, weiterhin dadurch gekennzeichnet, daß jede hohle Strebe (70, 71, 87) der Gruppe eine innere Kammer (72) aufweist, die zwei gegenüberliegende Seitenwände (70a, 70b), die an gegenüberliegenden axialen Enden konvergieren, um eine Vorderkante (70c) und eine Hinterkante (70d) zu bilden, eine radial innere Wand und eine radial äußere Wand, eine Einlaßöffnung (92), die in der radial. äußeren Wand gebildet ist, und eine Auslaßöffnung (74) bildet, die in der radial inneren Wand ausgebildet ist.

4. Spitzenspalt-Steuereinrichtung nach Anspruch 3, weiterhin dadurch gekennzeichnet, daß eine Luftleitanordnung (94) in jeder hohlen Strebe (70, 71, 87) der Gruppe angeordnet ist und zwei mit Löchern versehene Seitenwände (94a, 94b), die inneren Oberflächen der zwei Seitenwände (70a, 70b) von jeder entsprechenden hohlen Strebe (70, 71, 87) gegenüberliegen, und einen Einlaß (94f) hat, der mit der Einlaßöffnung (92) von jeder entsprechenden hohlen Strebe (70, 71, 87) verbunden ist.

5. Spitzenspalt-Steuereinrichtung nach Anspruch 1, weiterhin dadurch gekennzeichnet, daß die Quelle der Druckluft an einer der Verdichterstufen gewählt ist, und wobei die Leitung (90) eine Leitung ist, die von der gewählten Verdichterstufe zu jeder der hohlen Streben (70, 71, 87) der gewählten Gruppe von Streben führt.

**Revendications**

1. Dispositif de réglage du jeu en bout d'ailettes dans un turbomoteur (28) comportant une sec-

tion turbine (30) et une section compresseur (48) qui fonctionnent à partir d'un rotor commun (44) présentant un axe de rotor (60r), la section compresseur (48) comprenant une partie formant ensemble rotor du compresseur, qui contient plusieurs rangées d'ailettes de compresseur (52), rotatives, montées sur le rotor commun (44), et une partie formant ensemble stator du compresseur qui contient plusieurs rangées d'aubes de stator (56), montées sur le carter de stator (58) du compresseur, chaque paire de rangées adjacentes d'ailettes rotatives de compresseur (52) et d'aubes de stator (56) constituant un étage de compresseur, la section turbine (30) comprenant une partie formant ensemble rotor de turbine qui contient au moins une rangée d'ailettes de turbine (36, 38), rotatives, montées sur le rotor commun (44), chaque ailette rotative de turbine (36, 38) comportant un bout d'ailette, et une partie formant ensemble stator de la turbine qui contient au moins une rangée d'aubes de stator (80) montées sur un carter de stator (76) de la turbine et un auvent de stator (82, 84) monté sur le carter de stator (76) de la turbine de manière circonférentielle autour de chaque rangée d'ailettes rotatives de turbine (36, 38), chaque auvent de stator (82, 84) présentant un axe (60s) d'auvent de stator, l'axe (60r) du rotor coïncidant sensiblement avec l'axe (60s) de l'auvent de stator quand le moteur est à l'état froid, sans puissance, et quand le moteur fonctionne à faible puissance, le jeu en bout d'ailette étant défini comme un espace circonférentiel (86, 88) compris entre les bouts d'ailettes de turbine d'une rangée donnée qui tournent et une surface opposée de l'auvent de stator correspondant (82, 84) et étant sensiblement uniforme dans le sens de la circonférence lorsqu'il n'y a pas ou peu de puissance, l'axe (60r) du rotor étant positionné par rapport à l'axe (60s) du stator par des moyens formant paliers (62, 64) soutenus par une pluralité d'entretoises creuses (70-87) montées sur le bâti arrière de la section compresseur, les entretoises creuses (70-87) étant disposées radialement à intervalles angulaires égaux autour de l'axe (60r) du rotor, chaque entretoise (70-87) ayant un axe longitudinal sensiblement parallèle à l'axe (60r) du rotor, et une source d'air de refroidissement sous pression d'un débit proportionnel à la puissance du moteur, et un conduit (90) délivrant l'air de refroidissement sous pression à un groupe sélectionné des entretoises creuses (70, 71, 87) à une température suffisante pour induire une contraction thermique du groupe sélectionné d'entretoises creuses (70, 71, 87), s'opposant ainsi à un décalage vers le bas de l'axe (60r) du rotor pendant le fonctionnement du moteur à forte puissance et maintenant le jeu en bout d'ailettes uniforme dans le sens de la circonférence.

2. Dispositif de réglage du jeu en bout d'ailettes selon la revendication 1, caractérisé en outre en ce que le groupe d'entretoises creuses (70, 71, 87) est au-dessus d'un plan médian horizontal ($P_1$) du rotor (44) et centré sur un plan médian vertical du rotor.

3. Dispositif de réglage du jeu en bout d'ailettes selon la revendication 2, caractérisé en outre en ce que chaque entretoise creuse (70, 71, 87) du groupe contient une chambre intérieure (72) définissant deux parois latérales opposées (70a, 70b) qui convergent au niveau des extrémités axiales opposées pour former un bord d'attaque (70c) et un bord de fuite (70d), une paroi radialement intérieure et une paroi radialement extérieure, un orifice d'entrée (92) formé dans la paroi radialement extérieure et un orifice de sortie (74) formé dans la paroi radialement intérieure.

4. Dispositif de réglage du jeu en bout d'ailettes selon la revendication 3, caractérisé en outre en ce qu'un déflecteur d'air (94) est placé dans chaque entretoise creuse (70, 71, 87) du groupe et comporte deux parois latérales perforées (94a, 94b) qui font face aux surfaces intérieures des deux parois latérales (70a, 70b) de chaque entretoise creuse correspondante (70, 71, 87) et une entrée (94f) couplée à l'orifice d'entrée (92) de chaque entretoise creuse correspondante (70, 71, 87).

5. Dispositif de réglage du jeu en bout d'ailettes selon la revendication 1, caractérisé en outre en ce que la source d'air sous pression est l'un sélectionné des étages de compresseur, et dans lequel le conduit (80) est un tube allant de l'étage de compresseur sélectionné à chaque entretoise creuse (70, 71, 87) du groupe d'entretoises sélectionné.

FIG. 1

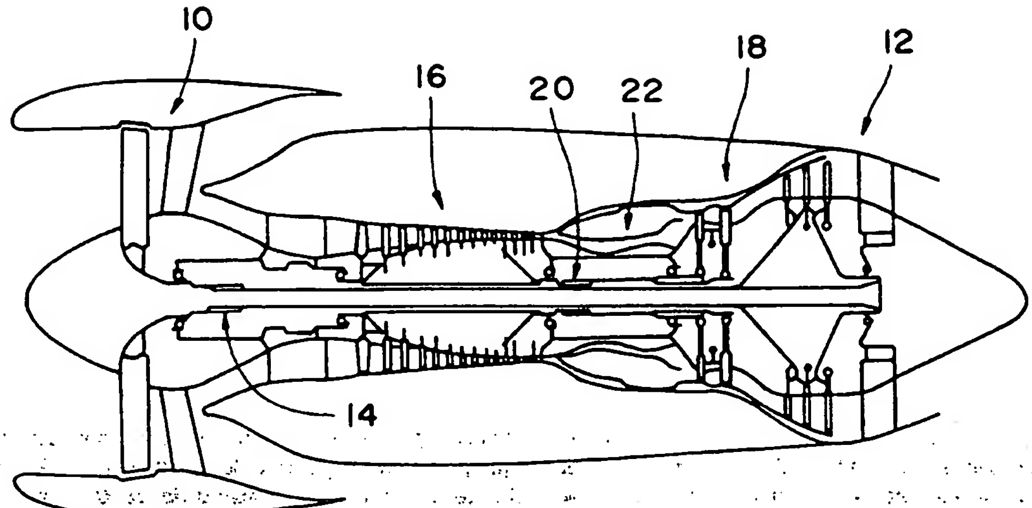



FIG. 2(a)
COLD

FIG. 2(b)
HIGH POWER

FIG. 2(c)
LOW POWER

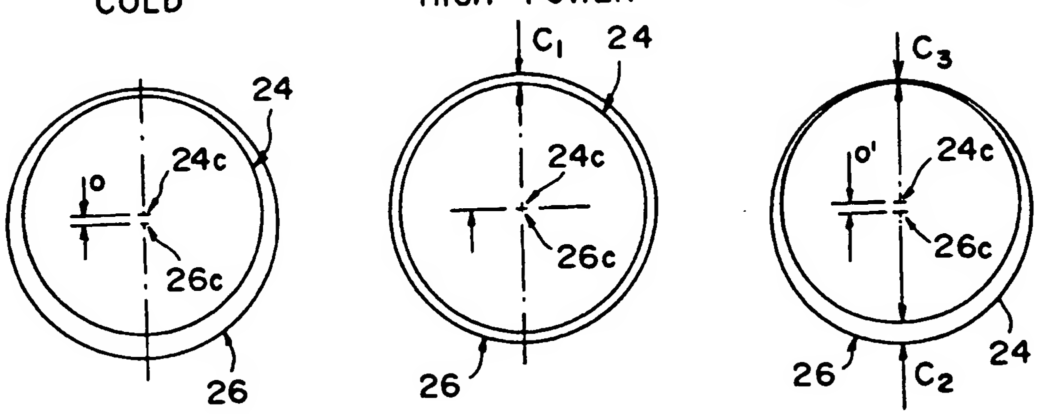


FIG. 3

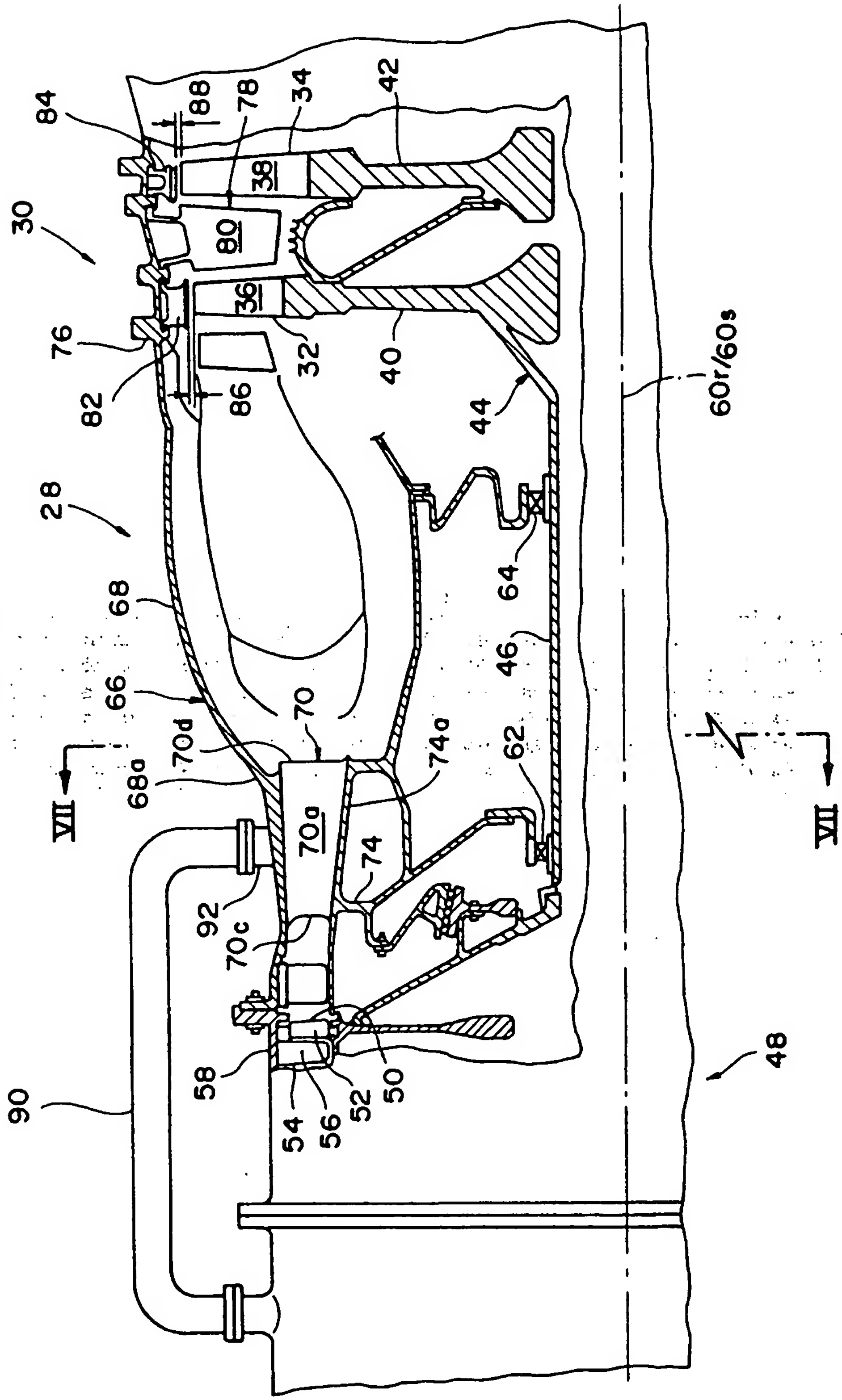

84
88
78
34
42
30
38
80
36
76
82
86
32
40
44
60r/60s
28
68
64
66
46
70
70d
74a
62
68a
VII
70a
VII
74
92
70c
90
58
54
56
52
50
48

FIG. 4

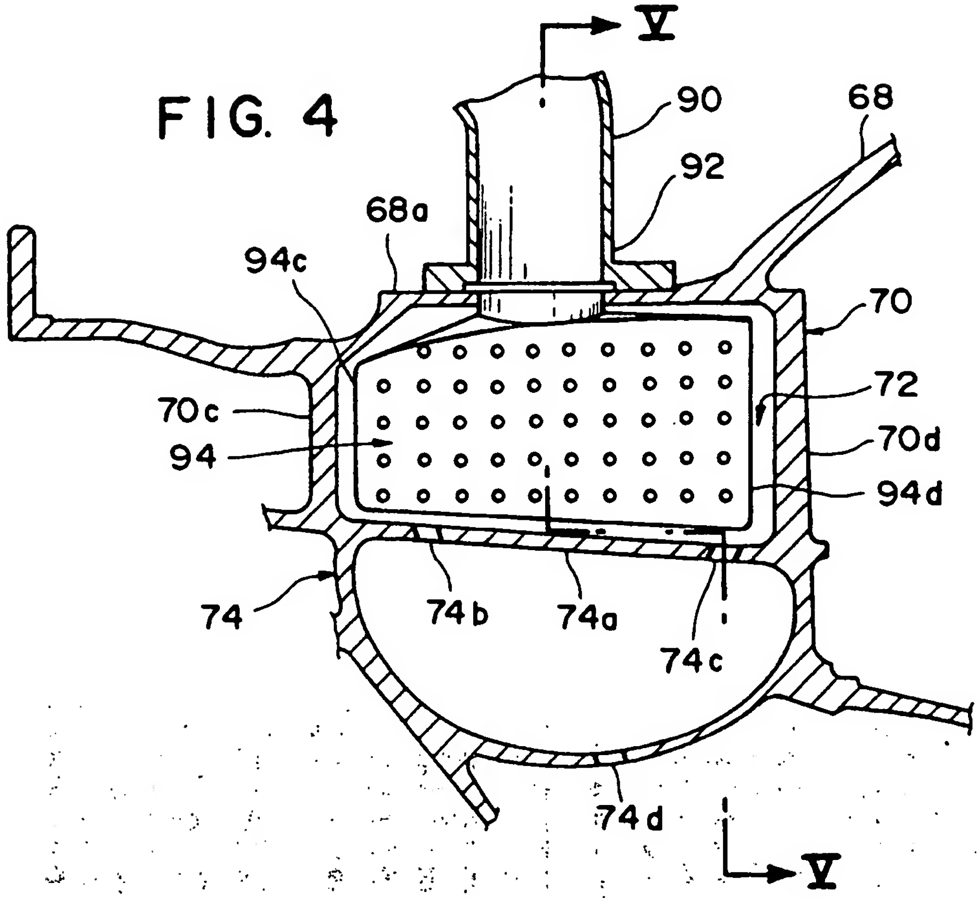



FIG. 5

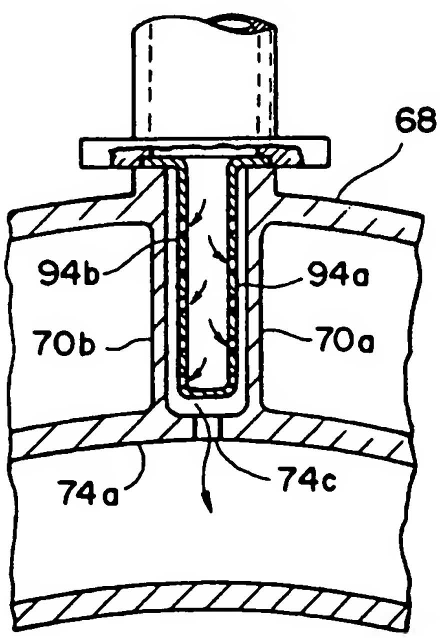



FIG. 6

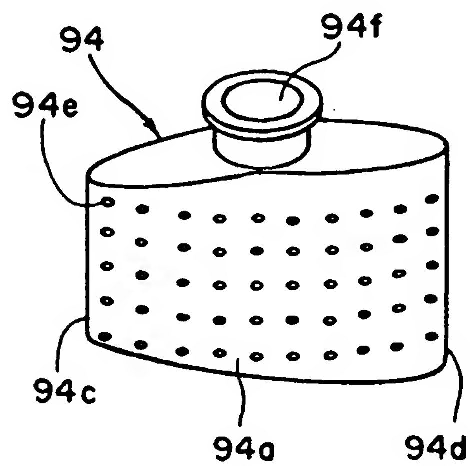
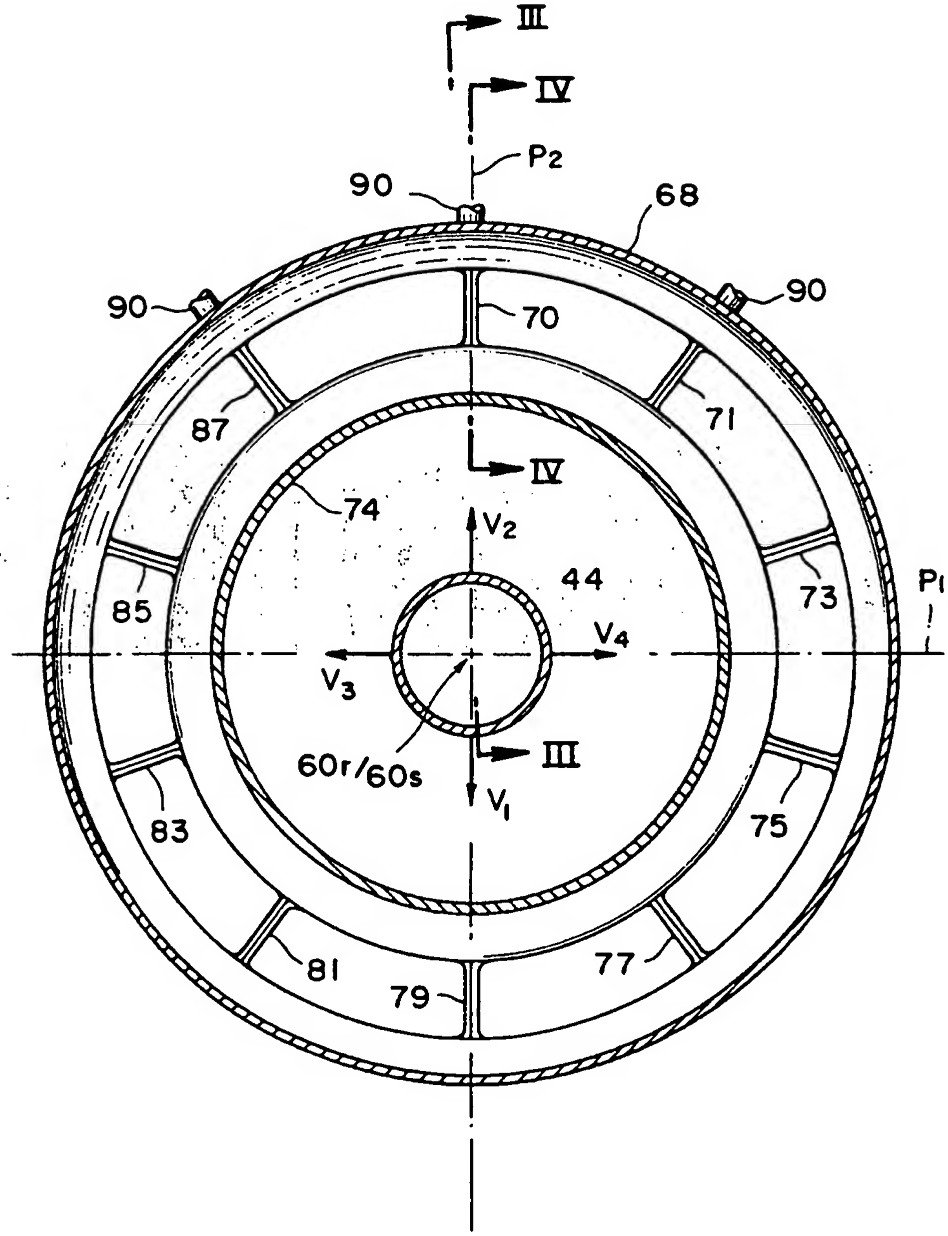


FIG. 7


III
IV
P2
90
68
90
70
87
71
IV
74
V2
44
85
73
P1
V4
V3
III
60r/60s
V1
83
75
81
79
77